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Investigation of winter wheat cold tolerance in Lithuania for breeding purposes

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SUMMARY

Over 900 winter wheat varieties from western and southhern Europe, western USA and International Maize and Wheat Improvement Centre's (CIMMYT) programmes were investigated in natural and artificial conditions at the Lithuanian Institute of Agriculture 1997–1999.

The best way to study winter hardiness was to investigate winter wheat varieties in natural conditions, or combine natural field growth with testing in freezing chambers. Winter hardiness positively correlated with plant height and grain yield.

The results show that 20–30% of West-European and 50–60% of varieties and lines from CIMMYT's programmes demonstrated the same resistance under Lithuanian winter conditions as local varieties. The most suitable varieties for hybridisation to improve winter hardiness were Yuna, Yuogtina, Nadia, Ukrainka odesskaja, Sirvinta, Flair, Zentos, Kosack.

Key words: cold tolerance, grain yield, plant height, winter wheat.

YFIRLIT

Athugun á frostþoli vetrarhveitis í Litháen með kynbætur að markmiði

Meira en 900 stofnar af hveiti úr kynbótaverkefnum frá suður Evrópu, vesturhluta Bandaríkjanna og Alþjóðlegu maís- og hveitikynbótastöðinni (CIMMYT) voru prófuð við náttúrulegar og tilbúnar aðstæður á Rannsóknastofnun landbúnaðarins í Litháen á árunum 1997–1999. Best reyndist að prófa hveitið við náttúrulegar aðstæður eða tengja saman akurtilraunir og frostþolspróf. Vetrarþol sýnir jákvæða fylgni við plöntuhæð og kornuppskeru. Niðurstöður sýna að 20–30% af vesturevrópskum stofnum og 50–60% af stofnum frá CIMMYT eru með svipað frostþol og heimastofnar við Litháiskar aðstæður. Álitlegustu stofnarnir til kynbótanota fyrir aukið frostþol eru Yuna, Yogtina, Nadia, Ukrainka odesskaja, Sirvinta, Flair, Zentos og Kosack.

INTRODUCTION

Lithuania is situated in the south-eastern part of the Baltic, between 54° and 56°N. The annual mean temperature of the country is 6.2°C. January is the coldest month and July the warmest, mean temperatures are –5.1 and +16.7°C, respectively.

The weather conditions during the winter-spring season are very changeable. The extremes in air temperature in January and February over the period 1990–1999 fluctuated between +8.7 and –26.8°C. The most important factor for winter survival of winter wheat is snow cover during winter. A general tendency of reduced quantity of snow in win-

ter was observed in the period 1925–1996 (Rimkus, 1999). Quite often low temperatures such as –15 to –16°C are interrupted by warm weather without snow, and this is harmful for winter wheat plants. Air temperatures below –20°C are considered dangerous. In the investigations conducted over the period 1901–1997 in Vilnius the following number of recurrences of anomalies were recorded: temperature < –20°C 72 years, temperature < –25°C 16 years and temperature < –30°C 2 years. Maximum anomalies (9–10°C) occurred in every decade of 1922–1931 and 1952–1971 and the minimum in 1972–1981 (Rimkus, 1999; Bukantis and Valiuskeviciene, 1999).

Winter wheat breeding in Lithuania was initiated in 1922. The first varieties 'Akuotieji' and 'Dotnuva 458' were developed on the basis of landraces. Later the initial materials for wheat breeding in Lithuania were varieties from Russia and Ukraine. Those varieties had in general good winter hardiness. The problems of those varieties were insufficient disease resistance and low grain yield. For the solution of these problems we included in winter wheat breeding programmes germplasm from western Europe and other regions. Winter hardiness tests then became very important.

Winter wheat is one of the most important crops in Lithuania. One of the key tasks in winter wheat breeding is to combine in new varieties high cold tolerance, high agronomic performance and good industrial quality of grain.

The winter wheat breeding programmes in Lithuania were renewed in 1990. In the hybridisation was included new germplasm from western Europe, USA, Russia, the Ukraine and other countries throughout CIMMYT's Winter Wheat Observation Nursery Programme. The main purpose of this study was to investigate cold tolerance of new germplasm from above mentioned regions and determine the relationship between cold tolerance, grain yield and height of wheat plants.

MATERIALS AND METHODS

The main investigations were done under natural conditions. Varieties and lines were sown with special sowing machines in 2 m^2 plots or two single rows in dry fields because the moisture content in the soil is one of the limiting factor for winter survival (Veisz and Tischner, 1995). Plots were fertilized annually with 60, 50 and 60 kg/ha of N, P and K, respectively. The evaluation in natural conditions was conducted in April on a 1–9 score basis. Score 1 means that all plants were killed, 9 that all plants had survived. By this method 200–300 accessions were analysed in the introduction blocks and 100–200 in collection blocks.

The second way to investigate cold tolerance were tests made under phytotronic conditions using sprouts. The grains, after sprouting to 3 mm sprout stage, were placed on a wet filter paper in special boxes, 100 kernel per replication. The boxes were kept for 7 days at 2°C for hardening (Veisz *et al.*, 1995). The cold test was made at –13°C and surviving plants were counted.

The third cold tolerance tests were made in the freezing chamber. The winter wheat seeds were planted in soil in special 4–5 cm deep boxes so that tillering node was at a depth of 3–4 cm, 100 plants in three or four replications. The boxes were then transferred to the field and kept for 12 weeks under natural conditions for hardening. In December the boxes were transferred to freezing chamber and the cold test was made in 1998 at –17°C and in 1999 at –14°C for 24 h with transitional periods of 24 h. Survival was recorded in the greenhouse after 2 weeks at 13–14°C.

Statistical evaluations were made using STAT_ENG and ANOVA programmes.

RESULTS AND DISCUSSION

This study included 314 varieties and lines from the International Wheat Observation Nursery Programme which CIMMYT collected in various countries, 203 varieties and lines from the International Winter and Spring Wheat

Screening Nursery (Western USA), 203 varieties from West Europe, 7 varieties registered in Lithuania, 7 new varieties bred at the Lithuanian Institute of Agriculture and 200 varieties from local genetic collection.

The results obtained from the analysis of this material revealed that winter hardiness was one of the main limiting factors for winter wheat grown under Lithuanian conditions. A significant positive correlation between winter resistance and grain yield was detected among the varieties originated from distant regions and western European varieties investigated in 1997 (Figure 1).

The correlation between grain yield and winter hardiness in West European varieties investigated in 1999 was negative and not significant. A disadvantage of the study of western European varieties in 1999 was lower number of accessions (73) and the fact that

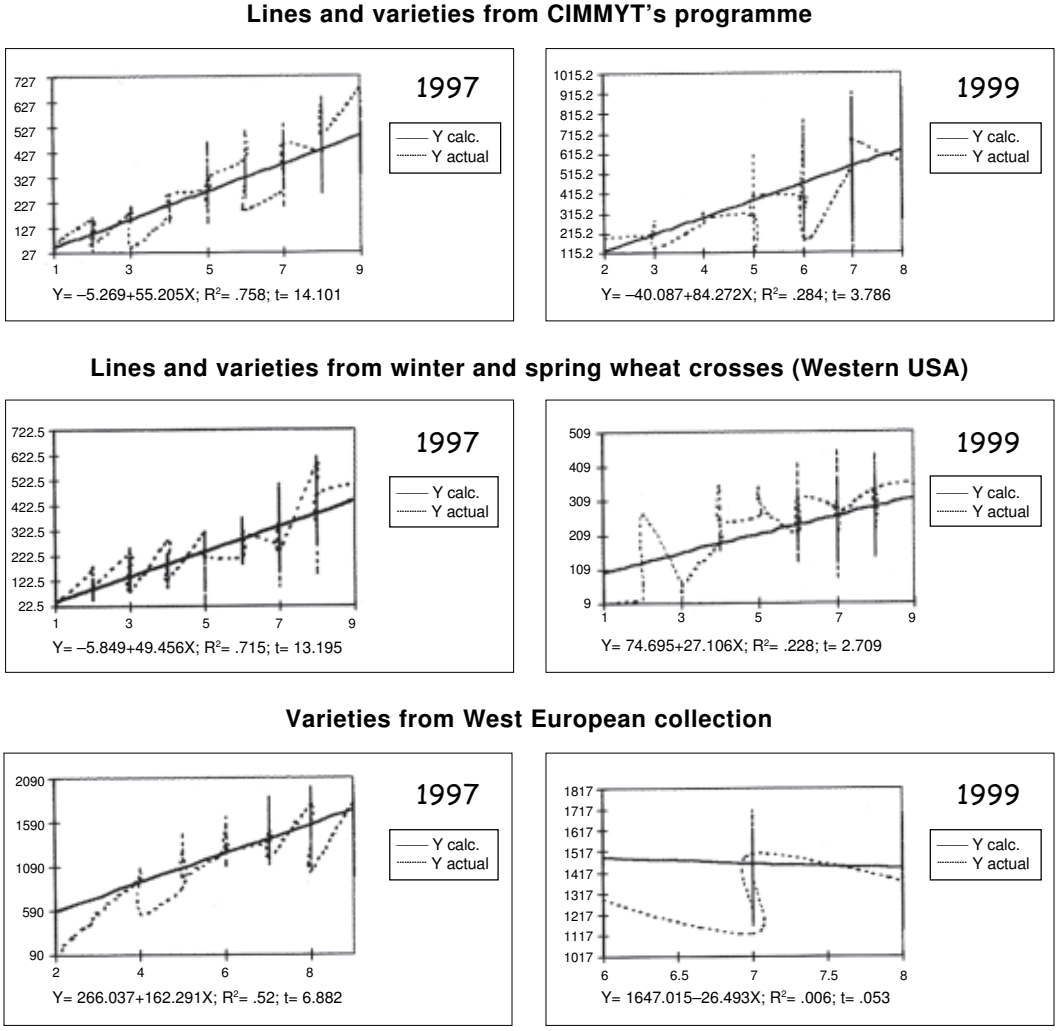

Figure 1. Relationship between winter hardiness and grain yield in winter wheat (X= winter hardiness, Y= grain yield).

1. mynd. Samband vetrarþols og kornuppskeru vetrarhveitis (X=vetrarþol, Y=kornuppskera).

these varieties were preliminarily selected for growing under Lithuanian conditions.

The opinion that winter-susceptible western European wheat varieties are more yielding than the resistant ones seems to apply for mild climatic conditions only. Higher positive correlation between yield and frost resistance occurred in years with low absolute air temperature (Fedulov, 1996).

In tests carried out in 1997–1999 a positive correlation between plant height and winter resistance was recorded (Figure 2). The main reason for this effect is that short growing varieties contain growth reducing genes, *Rht* series, which have negative impact on cold tolerance of winter wheat.

The most cold tolerant varieties from the CIMMYT's programme are: 'Yuna', 'Dakha' and 'Yougtina', collected in southern Russia; 'Nadia', 'Ukrainka odesskaja' and 'Fantasia

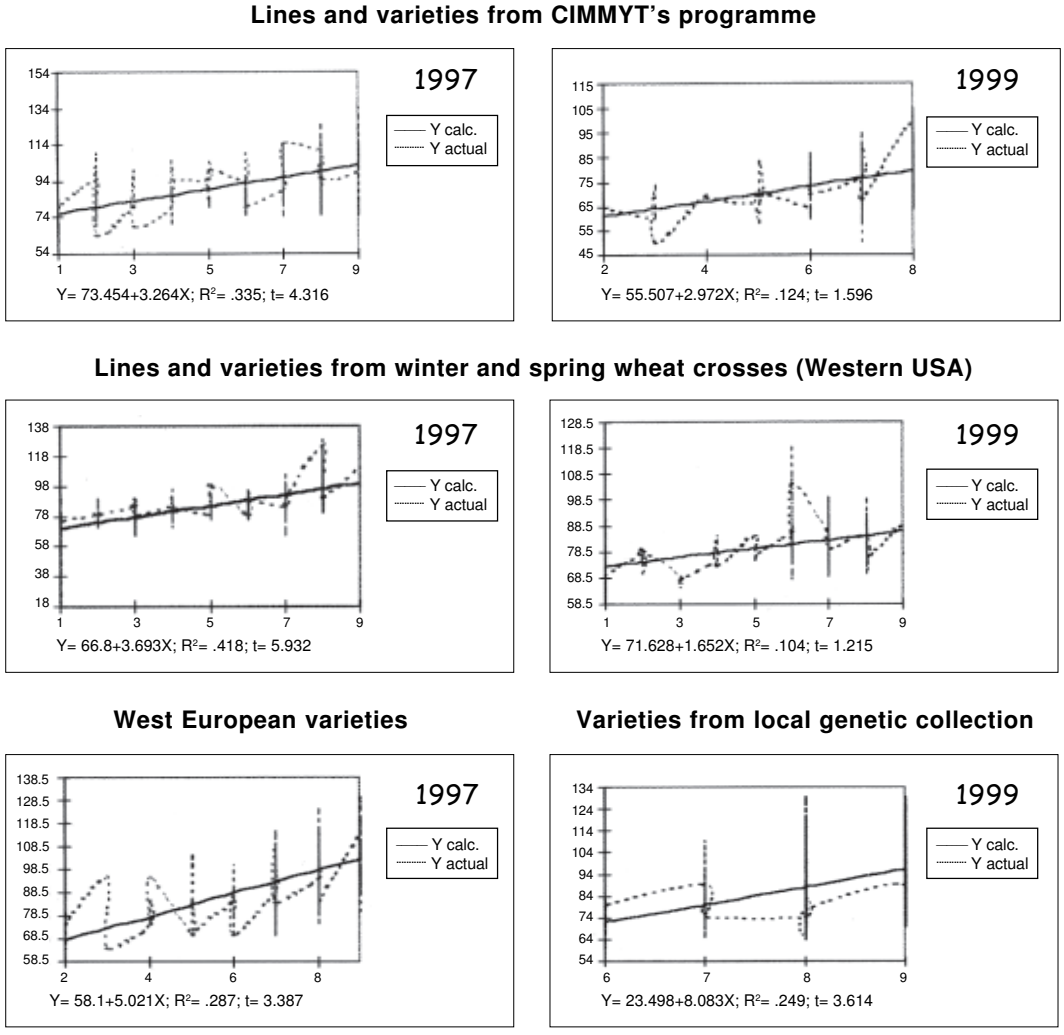

Figure 2. Relationship between winter hardiness and plant height (X= winter hardiness, Y= plant height).

2. mynd. Samband vetrarþols og plöntuhæðar (X=vetrarþol, Y=plöntuhæð).

odesskaja', from Ukraine; 'Flair', 'Zentos' and 'Kosack' from the western European collection.

In 1997 investigations were conducted on sprouts. The variety 'Volgogradskaja 84' had an extremely high cold tolerance. The varieties 'Sirvinta 1', 'Natalka', 'Miras' and 'Ramiro' had high tolerance and the varieties 'Inna', 'Albatross odesskij', 'Zentos' and 'Kosack' satisfactory tolerance. The test shows that the varieties 'Borenos', 'Trygve', 'Lutescens 8130', 'Aron' and 'Almari' had unsatisfactory cold resistance under Lithuanian climate conditions.

Results from investigations using sprouts sometimes did not correlate strongly with results of field winter hardiness. Some authors have noticed that it is reasonable to combine frost resistance test in the field and the laboratory (Gut *et al.*, 1993). Therefore in 1998 and 1999 we initiated investigations of new registered and new homebred varieties in special boxes keeping them in the field and testing in the freezing chambers. In 1998 the test temperature was –17°C. In 1999 test temperature was reduced to –14°C. In nature, when the air temperature is –15° or –18°C and there is no snow cover, the temperature 5 cm below the surface where the tillering node is located is only –5° to –7° (Veisz *et al.*, 1995).

The experiments resulted in a high degree of low temperatures tolerance among the varieties 'Sirvinta', 'Alma', 'Ada' (1998) and 'Alma', 'Ada', 'Tauras', 'Sirvinta', 'Lina', 'Bussard' (1999) (Figure 3).

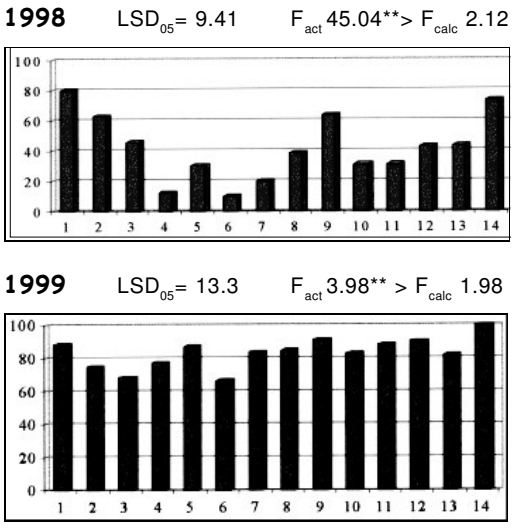

Figure 3. Cold tolerance of 14 winter wheat varieties registered in Lithuania and new varieties bred at LIA. (1) Sirvinta (st.), (2) Zentos, (3) Portal, (4) Alba, (5) Bussard, (6) Ibis, (7) Begra, (8) Kena, (9) Ada, (10) Seda, (12) Lina, (12) Tauras, (13) Milda and (14) Alma.
3. mynd. Frostþol 14 stofna af vetrarhveiti skráð í Litháen og nýrra stofna kynbættra á Rannsóknastofnun landbúnaðarins í Litháen.

CONCLUSION

Results of cold tolerance and winter hardiness tests revealed that to use West European or distant origin germplasm for production of intervarietal hybrids it is necessary to screen it for low temperature tolerance.

The best ways to study winter hardiness is to investigate the varieties in natural conditions or combine natural field growing and testing in freezing chambers.

The winter hardiness of winter wheat positively correlated with plant height and grain yield.

The results showed that 20–30% of West European and 50–60% of distant origin varieties demonstrated the same resistance to the Lithuanian winter conditions as local varieties.

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